Advanced molecular 'sieves' could be used for carbon capture

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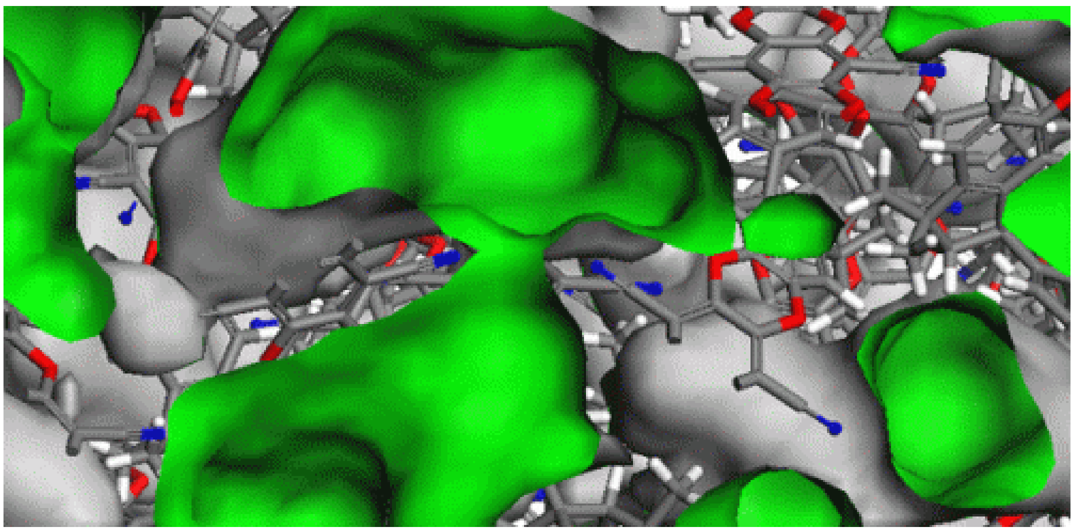

Polymer molecular sieves with interconnected pores (in green) for rapid and selective transport of molecules. Credit: Qilei Song

(Phys.org) —Researchers from the University of Cambridge have developed advanced molecular 'sieves' which could be used to filter carbon dioxide and other greenhouse gases from the atmosphere.

Newly-developed synthetic membranes provide a greener and more energy-efficient method of separating gases, and can remove carbon dioxide and other greenhouse gases from the atmosphere, potentially reducing the cost of capturing carbon dioxide significantly.

The synthetic membranes, made of materials known as polymers of intrinsic microporosity (PIMs), mimic the hourglass-shaped protein channels found in biological membranes in cells. The tiny openings in these molecular 'sieves' – just a few billionths of a metre in size – can be adjusted so that only certain molecules can pass through. Details are published in the journal *Nature Communications*.

Current methods for separating gases are complex, expensive and energy-intensive. Additionally, conventional polymers, while reliable and inexpensive, are not suitable for large scale applications, as there is a trade-off between low permeability levels and a high degree of selective molecular separation.

Researchers are attempting to develop new methods of energy-efficient and environmental-friendly membrane-separation technology, which is an essential process in everything from water purification to controlling gas emissions.

The team from the University's Cavendish Laboratory, working with researchers from Kyoto University, has developed an alternative approach to generating polymer membranes, 'baking' them in the presence of oxygen, a process known as thermal oxidation.

Inducing a thermal oxidation reaction in the PIMs causes the loosely-packed long chains of polymer molecules to form into a cross-linked network structure, with hourglass-shaped cavities throughout. This structure not only results in a membrane which is more selective to gas molecules, but also the size of necks and cavities can be tuned according to what temperature the PIMs are 'baked' at.

"The secret is that we introduce stronger forces between polymer chains," said Dr Qilei Song of the Cavendish Laboratory, the paper's lead author. "Heating microporous polymers using low levels of oxygen produces a tougher and far more selective membrane which is still relatively flexible, with a gas permeability that is 100 to 1,000 times higher than conventional polymer membranes."

The cross-linked structure also makes these membranes more stable than conventional solution-processed PIMs, which have a twisted and rigid structure - like dried pasta - that makes them unable to pack efficiently. Thermal oxidation and crosslinking reinforces the strength of channels while controlling the size of the openings leading into the cavities, which allows for higher selectivity.

The new membrane is twice as selective for separation carbon dioxide as conventional polymer membranes, but allows carbon dioxide to pass through it a few hundred times faster. These thermally modified PIMs membranes are among molecular sieves with the highest combinations of gas permeability and selectivity. In addition to possible uses for separating carbon dioxide from flue gas emitted from coal-fired power plants, the membranes could also be used in air separation, natural gas processing, hydrogen gas production, or could help make more efficient combustion of fossil fuels and power generation with much lower emissions of air pollutants.

"Basically, we developed a method for making a polymer that can truly contribute to a sustainable environment," said Professor Easan Sivaniah from Kyoto University's Institute for Integrated Cell-Material Sciences (iCeMS).

"This new way of modifying PIMs brings the prospect of large-scale, energy-efficient gas separation a step closer," said Professor Peter Budd, from the University of Manchester, one of the inventors of PIMs materials.

More information: "Controlled thermal oxidative crosslinking of polymers of intrinsic microporosity towards tunable molecular sieve membranes." Qilei Song, et al. *Nature Communications* 5, Article number: 4813 DOI: 10.1038/ncomms5813

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